LAIR REPORT NO. 37

PROJECT SATAN
(STROBES AGAINST TROOPS AT NIGHT)

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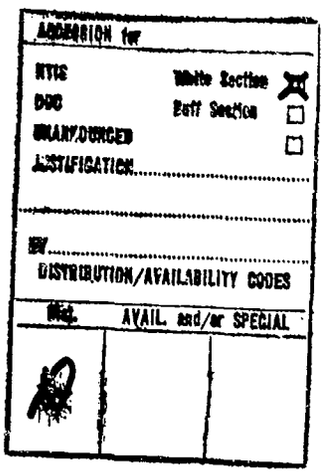

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Project SATAN (Strobes Against Troops at Night) was conducted at Fort Hood, Texas. A pre-pilot study (in two phases) and main test were performed between 14 and 16 May, 27 May and 6 June 1975. The main field study was designed to examine the performance of soldiers under stroboscopic illumination and to record any psychophysiological effects of the experience. A modified 5 kilowatt xenon-arc lamp system was mounted on a tank. The illumination was directed from given positions in relation to the men, the targets, and the terrain. Marksmenship, transversing the terrain, and timed hand-eye coordination tasks

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were performed under several conditions: continuous wave, 6 Hz at 13.5% and 50% duty cycle conditions. Nineteen soldiers participated in the main field test. Results of the tests and experience indicated that all personnel involved in the project had substantial subjective effects from the strobic illumination. Data analyzed from the timed tasks for eye-hand coordination indicated that learning the task affected the scores more than the frequency and duty cycle of the stroboscopic source. Future field studies should be conducted under controlled conditions and the tasks should be those in which the anticipated disruptive effects could be easily detected in humans. Then more sopisticated field tests under stroboscopic illumination with various stimuli and terrain conditions could be accomplished with tasks identified as critical to the conduct of the mission.

ABSTRACT

Project SATAN (Strobes Against Troops at Night) was conducted at Fort Hood, Texas. A pre-pilot study, pilot study (in two phases), and main test were performed between 14 and 16 May, 27 May and 6 June 1975. The main field study was designed to examine the performance of soldiers under stroboscopic illumination and to record any psychophysiological effects of the experience. A modified 5 kilowatt xenon-arc lamp system was mounted on a tank. The illumination was directed from given positions in relation to the men, the targets, and the terrain. Marksmanship, transversing the terrain, and timed hand-eye coordination tasks were performed under several conditions: continuous wave, 6 Hz at 13.5% and 50%, and 9 Hz at 13.5% and 50% duty cycle conditions. Nineteen soldiers participated in the main field test. Results of the tests and experience indicated that all personnel involved in the project had substantial subjective effects from the strobic illumination. Data analyzed from the timed tasks for eye-hand coordination indicated that learning the task affected the scores more than the frequency and duty cycle of the stroboscopic source. Future field studies should be conducted under controlled conditions and the tasks should be those in which the anticipated disruptive effects could be easily detected in humans. Then more sophisticated field tests under stroboscopic illumination with various stimuli and terrain conditions could be accomplished with tasks identified as critical to the conduct of the mission.

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INTRODUCTION

The deployment of high intensity tank mounted xenon arc lamps to illuminate terrain and personnel during military operations has occurred within the past several years. Modification of these systems in order to operate in a pulsed mode creates several practical problems when used on the battle field. These problems can be roughly placed into two categories. In the first, concern is directed towards the hazardous effects of the light upon visual processes in either the continuous wave (cw) or pulsed mode. The second relates to effects upon the psychophysiological and orientational responses of exposed personnel. In the former case, an analysis of the specific system (AN/VSS-3A searchlight [modified]) was completed by personnel from the USAEHA. In general, it was recognized that the system was hazardous under certain beam configurational conditions for distances up to 3 km with the unaided eye.[1]

The effects of stroboscopic illumination at low energy levels at frequencies between 2 and 30 hertz (Hz) have been studied.[2] Of the symptoms observed, photoconvulsive responses have been the most thoroughly described. The most effective frequencies in production of this response were found to be between 8 and 20 Hz. Other phenomena which have been reported are vertigo, nausea, disorientation, headache, anxiety, irritability, and decreased eye-hand coordination.

Project SATAN, Strobes Against Troops at Night, was introduced to the Division of Non-Ionizing Radiation (DNIR) by telephonic inquires from the project officers at the Modern Army Selected System Test Evaluation and Review (MASSTER), Fort Hood, Texas, in November 1974.

Several addenda to the original MASSTER SATAN program were received at LAIR in the following months. The most important were two hazard evaluations. The first, performed with the assistance of the Technology Branch, Office of the Deputy Chief of Staff for Operations at MASSTER, was an analysis of the eye hazard associated with the modified AN/VSS-3A searchlight.[3] The conclusions in the report emphasized that "Laboratory experiments should be conducted by trained medical personnel before the field phase of this experiment is conducted." A second hazard analysis by USAEHA recommended safe viewing distances for the strobe system.[4]

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[1]Franks, J. K., et al., Radiation Protection Special Study No. 42-0074-75, AN/VSS-3A Searchlight (Modified) for Project SATAN, 1974.

[2]Procopis, P. G., et al., Arch Neurol, 31:31, 1974.

[3]Technical Report on Eye Safety for SATAN, MASSTER Test No. FN 258.

The present paper is a report of the (1) pre-pilot study measurement and familiarization, (2) pilot study (Phases I and II), and (3) main field study which was designed to examine the effects of stroboscopic illumination upon the performance of soldiers in a field situation. A description of the stroboscopic variables and tasks used in each of the studies is presented. Of the four military tasks and the two standard tests included in the design, the most complete data obtained for analysis were collected from the Pursuit Rotor test. Although such subjective effects as sense of movement of the target defy statistical analysis, the force of the unpleasant subjective effects noted by all personnel involved in the study was substantial.

PRE-PILOT STUDY

MATERIALS AND METHODS

Illumination measures were made of the AN/VSS-3A (modified) 5 kilowatt (kW) xenon arch lamp system during a night-trial with a Tektronix probe (MDL J16). The terrain was an uneven compacted rock parking lot in the immediate area and a uniformly grassy hill in the distance. Measurements of reflectances from objects at a distance and from ground surfaces were taken when illuminated by the 5 kW source and by a hand-held portable system.

The subjects involved in the pre-pilot study were LAIR and MASSTER personnel. Subjective psychophysiological and coordination (eye-hand, eye-foot) effects were summarized from the comments of the personnel as they described the experience retrospectively. The 5 kW source was turned on 50 to 300 meters behind the personnel and was operated at pulse frequencies varying from 6 to 12 Hz. Several other factors were introduced, such as a flashlight which illuminated objects on the ground, narrow band pass interference filters to change chromaticity and, while in the strobe beam, one eye was closed. The Farnsworth 100 hue test of color vision was given before the pre-pilot test and again one-hour after the field observations.

RESULTS AND DISCUSSION

At approximately 75 meters, the reflectance from a light tan jacket yielded 5 to 8 foot Lamberts. Ground surface reflectance was 5 to 7 foot Lamberts at the same distance. The hand-held portable system yielded reflectances from the ground surface of approximately 4 foot Lamberts at a distance of 10 meters from the strobe.

The psychophysiological sensations experienced by the LAIR and MASSTER personnel during the field test were minimal with the hand-held system. With the 5 kW source at distances which varied from 50 to 300 meters behind the personnel, the subjective effect upon those present was described as an inability to accomplish gross eye-hand and eye-foot coordination movements. The apparent motion of the ground at a pulse frequency of 5 to 6 Hz was disconcerting. Small ditches were difficult to traverse. This motion effect of the strobe diminished as the target became more uniform. Thus, light reflected from a uniformly grassy hill resulted in less of a stroboscopic effect than illumination reflected from non-uniform areas such as trees and broken terrain. When the frequency of the strobe was varied, the greatest disorientational effects were seen at 5 to 6 Hz. When the strobe was operated at 9 Hz or greater. these effects were greatly diminished. The disruptive effects upon coordination were almost completely obviated by the use of flashlight or when other cw sources were directed toward objects in the field or the ground in front of the individual. With the narrow ban pass interference filters, the brightness of the strobe light decreased and the color changed, but the effect of the strobe at 6 Hz persisted. Closing one eye also appeared to diminish the disorienting effects of the strobe. No changes in color vision were detected on the Farnsworth 100 hue test of color vision nor did any of the participants report any physiological discomfort one hour after the field observations.

PILOT STUDY

PHASE I. Marksmanship with the M-16 rifle.

MATERIALS AND METHODS

Two marksmen with night observation devices (NODs) and two men with unaided vision were equipped with 20 rounds apiece (two 10-round clips) and an M-16 rifle each. They were required to shoot at target silhouettes placed 25 and 75 meters in front of them with the strobe operating at 6 and 9 Hz frequency conditions at a 13.5% lamp duty cycle. Two firers were accommodated simultaneously. The iterations were as follows:

1. Darkness. No strobe.

2. Darkness. Strobe placed approximately 30 meters behind the firers and operated first at 6 Hz and then at 9 Hz.

3. Same iterations with marksmen who had the NODs.

4. Strobe was moved to a tank placed to the left front of the firers, approximately 250 meters away with the targets placed 75 meters to the front of the firers. The strobe illuminated both the target (backlighted) and the firers.

RESULTS AND DISCUSSION

The results of this phase of the field pilot study indicated the following:

1. At 25 meters, i.e. point blank range, both groups of firers (those with NODs, those without NODs) obtained 90 to 100% accuracy with the M-16 rifle both with and without the strobe conditions.

2. At 75 meters, the marksmen had as many misses under the no strobe condition as under the strobe light. (The results had to be discounted because the rifles had not been sighted for this range.)

3. The soldiers with the NODs occasionally fired at the same target at the 75 meter distance. This resulted in many hits on one target and zero on the other.

4. Glare from the strobe placed in front of the firer occluded the NODs but provided enough backlighting of the target for detection without NODs. As a result, the NOD firers attempted to fire by using their regular sights.

5. The firers reported that they closed their left eye when firing. This reduced glare from the light on the tank to their left. Two of the soldiers fired left handed which further confounded the evaluation of the stroboscopic effects.

6. After the test, th soldiers indicated that they had no discomfort except for the glare They did sense an apparent "movement" of the target at the 6 Hz condition with the strobe placed to the rear and they reported that they had been distracted by this "movement."

7. No differences were seen in the results of the Farnsworth 100 hue tests which were administered to the firers before the test and immediately after they returned from the firing line.

PHASE II. Night terrain course.

MATERIALS AND METHODS

The design for the second phase of the pilot test consisted of a night terrain course that started 50 meters from the tank-mounted strobe system. The subjects were to traverse the course on foot and to stop at designated spots to perform timed tasks. They were to perform the exercises both going away from the tank and returning toward the tank. Half of the participants wore night observation devices (image intensifiers) under the 6 and 9 Hz stroboscopic conditions.

The timed tasks, which were set up at each position, required the soldier to tune a radio to the correct frequency, change barrels on a machine gun, mount a machine gun on a tripod, load ammunition clips (M-16) with blank cartridges, and to insert unloaded ammunition clips into M-16 rifles.

RESULTS AND DISCUSSION

Interviews with each soldier following the task and terrain course exercise indicated no effects of the strobe except for difficulties encountered (because of the glare of the light source) when they were required to return toward the strobe.

Performance on both the terrain course and the various tasks were inconclusive. The soldiers used as test subjects were not familiar with the course in daylight, and consequently, there was no baseline against which the timing of the night terrain course could be compared under strobe conditions, no strobe conditions, or with image intensifiers. Also, some of the soldiers were not familiar with some of the tasks (some of the participants reported that they had not handled a machine gun before). All of the soldiers went to each station, attempted to perform the task, and went on to the next station. Some troops ran the course, while others had difficulty traversing it under all conditions. Elapsed time on the course could not be compared meaningfully either between subjects or among subjects or tasks.

MAIN STUDY

A number of regulations and observations made during the exploratory testing periods dictated the scenario for the Main Study of Project SATAN.

In accordance with AR 40-46,[4] participating individuals were given pre-test eye examinations which included visual acuity, the Farnsworth 100 hue test, a slit lamp examination, funduscopic examination and fundus photographs. Additionally, each was screened for a history of epileptiform seizures or migraine headaches. Approximately 145 potential participants were screened by a LAIR representative and the staff of Darnell Army Hospital. Seven soldiers were rejected because of previous eye disease.

Results of the marksmanship portion of the test had indicated that no matter which searchlight was used, at 25 meters without NODs and at 75 meters with NODs, targets were hit with 80 to 100% accuracy. The firers had commented (in post-firing interviews) that they sensed no adverse effects upon their firing of the iterations used, except at the 6 Hz at 13.5% condition, where the targets appeared to be moving. They reported this as "bothersome" and most of the men reported that they had some difficulty aiming. They reported no adverse effects at the 9 Hz at 13.5% and the 6 and 9 Hz at 50% condition. They all reported that the light did not appear even to flicker at the 9 Hz, 50% duty cycle. It was viewed as a cw source with fluctuations in illumination of the target, i.e. no dark-time discernible.

Based upon analyses of these data, several changes were made in the firing sequences. The 50% system was switched to a cw mode. The targets were moved back to 75 meters for the naked-eye shooters and to 150 meters for the NOD group. The 6 and 9 Hz at 50% conditions were removed from the tasks (since they were considered analogous to cw).

MATERIALS AND METHODS

The test plan for the main study was similar to the plan outlined in the pilot study except for the addition of the timed tasks and the use of the 1 kW, 50% duty cycle strobe.

Several groups were tested under the format iterations which consisted of a continuously illuminated target and a strobe operating at both 6 and 9 Hz at 13.5% duty cycle.

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[4]AR 40-46, Control of Health Hazards from Lasers and Other High Intensity Optical Sources, 6 February 1974.

A variation was introduced to the tests on the third night. The strobes were arranged to the right front of the shooters at approximately 380 meters distance. The same sequences, incuding the use of the NODs, were tested except that the targets were moved approximately to 75 meters so that the strobe, when directed at the firers, would also silhouette the targets. Lights were placed behind sandbags at the base of the target to insure that the targets could be seen by the non-NOD users. The two NOD firers shot at red illuminated targets while the non-NOD firers shot at white light illuminated targets. The firers were also tested under the original test plan and shot at 6 and 9 Hz, 50% pulse width conditions.

During the two nights of terrain and task testing, a tank mounted strobe system was used to illuminate the tasks. The tasks were laid out on target cloth, a heavy burlap type of material with approximately 40 to 50% reflectivity. The Purdue Pegboard and the Pursuit Rotor system tests were set up. The tests began at approximately 2300 hours. Task orientation was done under cw illumination from the tank's xenon searchlight mounted on the back of a truck placed approximately 30 meters from the tasks. All personnel were instructed not to look back at the light at any time. The tasks began with ... tary tasks and concluded with the finger dexterity and the pursuit rotor tests. The six tasks are listed as follows (tasks 1 through 5 were timed):

1. Change a machine gun barrel (take barrel out, insert another, take that one out and put the original one back in).

2. Load ten rounds apiece (blanks) into two M-16 ammunition clips and then unload them.

3. Set up a tripod and mount a 30 caliber machine gun upon it then disassemble the unit.

4. Load and unload magazines into an M-16 rifle (three iterations).

5. The Purdue Pegboard test in which finger dexterity for the right hand, left hand, and both hands were measured.[5]

[5]Examiners Manual for the Purdue Pegboard. Chicago: Science Research, 1961.

6. The Pursuit Rotor test is a test in which the subject is required to follow a square of light with a light sensing wand along a circular path for two minutes at a rotational speed of 20 revolutions per minute.[6] Time on target was taken as the score.

On the first night, 11 subjects were run under three light conditions (cw, 6 Hz at 13.5% and 9 Hz at 13.5%). The following night, the iterations which were given during the tasks situation were performed under cw and 6 Hz at 50% condition. Eight subjects, in addition to the 11 subjects tested on the first night, were run on the second night.

An analysis of variance[7] was performed on the first 11 subjects who had been scored on all five conditions.

RESULTS AND DISCUSSION

In the marksmanship portion of the main test, a preliminary analysis of the data showed no differences in any of the conditions when either hits on target or time to fire were used as criterion. The results of the post-test interviews with the firers indicated that (1) glare created greater problems in both the cw and 50% conditions than in the 13.5% duty cylce conditions, (2) apparent movement of targets was markedly less in the strobe-in-front iterations, (3) the phosphor in the scope of the NODs became saturated and the firers who had NODs also reported that they had aimed their weapons through the regular sights and that scopes partially blocked the glare. The outline of the target could be seen because of the light placed at the base of the target, and (4) the scores were lower and shooting times longer at 6 Hz than at 9 Hz and cw.

An accurate summary of the military tasks is not available. No analysis was made on the pegboard test results because data were incomplete. The data from the Pursuit Rotor test for the 11 subjects who participated two consecutive nights appear to be complete and available for analysis.

The Pursuit Rotor mean scores (time on target for a two minute trial) are given in the order in which they were obtained: cw condition, 34 sec; 6 Hz at 13.5%, 26 sec; and 9 Hz at 13.5%, 40 sec. The

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[6]Cronback, L. J. Essentials of Psychological Testing (2nd ed). New York: Harpers, 1960, pp 303.

[7]Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

following night the mean pursuit rotor scores for the same 11 subjects were cw, 46 sec; and 6 Hz at 50%, 52 sec. These scores indicated that there was no need to do the 9 Hz at 50%.

The 8 persons, who joined the group of 11 on the second night had lower scores than the group of 11 (cw, 24 sec; 6 Hz at 50%, 35 sec), showed a definite learning trend such as the basic group of 11 persons had shown. It was not possible to re-run the test for these 19 subjects to verify the apparent reduced time scores.

The results of the statistical analysis on the first 11 subjects who had been scored in all five conditions indicated that the mean square difference between subjects was substantially less than the mean squares within subjects. The F-test indicated a high degree of significance: $F_{.99}(4,40) = 3.83$ for an F ratio of 24.24 (Table I). An aposteriori test was then applied to the data to determine the source of this variance. Table II shows the results of the Newman-Kuhls test on ordered totals following the finding of an overall significant analysis of variance.

The interpretation of these results is as follows:

1. The 6 Hz at the 13.5% duty cycle was significantly different from 9 Hz at 13.5%, 6 Hz at 50%, and the second cw condition ($p \leq 0.01$). No significant difference was seen between the first cw condition and 6 Hz at 13.5%.

2. The first cw condition was significantly ($p \leq 0.01$) different from the second cw and the 6 Hz condition but not significantly different from the 9 Hz at 13.5% condition.

3. Since B (Table II) or 6 Hz at 13.5% was no different than the cw condition and was significantly lower for the remaining conditions, and since a significant difference existed between both the cw conditions, the indications are that (a) perceptual motor skills are more dependent upon a learning paradigm than upon strobe effects, and (b) training of subjects pre-experimentally must be accomplished before undertaking tasks in which learning plays a major role.

Post test ophthalmoscopic examinations were conducted upon 56 of the original 145 participants. No visual problems were reported by any of the subjects nor did comparisons of the Farnsworth 100 hue test, fundus photographs, and slit lamp examinations show any changes.

GENERAL CONCLUSIONS

The subjective effects noted by all personnel involved in the field study were substantial. They ranged from apparent movement of the targets during range firing of the M-16 rifle to a decrease in eye-hand coordinated activity.

RECOMMENDATIONS

In the light of the observations made during Project SATAN, a controlled study should be carried out. The tasks included in the experimental designs should be tasks in which the anticipated disruptive effects would be easily detected in humans. Elements of these tasks, which would be directly applicable to the field situation, could then be defined in the context of a field situation. Field tests of the effects of stroboscopic illumination under various stimuli and terrain conditions could then be accomplished with tasks identified as critical to the conduct of a mission.

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APPENDIX

TABLE I Analysis of Variance

TABLE II Newman-Kuhls Test of Ordered Totals

TABLE I

Analysis of Variance

Source of Variance	SS	df	MS	F
Between People	620.80	10		
Within People	10,345.66	44		
Lights	7,324.22		1,831.06	24.24*
Residual	3,021.43	40	75.54	
TOTALS	18,283.67			

*$F_{.99}$ (4,40) = 3.83

TABLE II

Newman-Kuhls Test of Ordered Totals

Light Condition:	6 Hz 13.5%	CW1	9 Hz 13.5%	CW2	6 Hz at 50%
Presentation Order:	B	A	C	D	E
Ordered Totals:	284	371	435	510	576

Truncated Range, r	=	2	3	4	5
q.99(r,40)	=	3.82	4.37	4.70	4.93
q.99(r,28) nMs error	=	110.12	125.97	135.48	142.11

	B	A	C	D	E
B	-	87	151*	226*	292*
A		-	64	139*	205*
C			-	75	141
D				-	66
E					-

*Significant at ($p \leq .01$) on studentized range distribution.

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